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Neural correlates of cross-alphabetic interference and integration in the biliterate brain

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Research Article

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Abstract

We investigated the neurophysiological mechanisms underlying bi-alphabetic reading using event-related potentials (ERPs). Brain activity was recorded using EEG in a group of Russian–English biliterates during a reading-aloud task with familiar and novel words. Capitalizing on a partial overlap between the Roman and Cyrillic alphabets, the stimuli were presented in L1 Cyrillic, L2 Roman, or in an ambiguous script, in a counterbalanced fashion. The results revealed functional dissociation between the stimuli in terms of processing their graphemic ambiguity. The interference caused by L1-L2 script inconsistencies in novel wordforms was detected at a late processing stage, reflected in N400 response enhancement for unfamiliar script-ambiguous items. Conversely, familiar ambiguous and L2 words showed no N400 increase but demonstrated an early enhancement of the P200 component in comparison to those presented in L1. These results indicate the use of a whole-word reading strategy for familiar words even in ambiguous script, likely triggered by an automatic activation of well-established lexico-semantic representations. The absence of similar top-down mechanisms for novel ambiguous-script words likely results in increased grapheme-to-phoneme decoding effort, with important implications for L2 reading and vocabulary acquisition.

Introduction

Bilingualism, and especially the use of English language as a second language (L2), is imperative for academic and professional success. In this sense, English proficiency ensures a successful integration within a continuously growing globalized community where this language has been established as a common mode of communication in both spoken and written modalities. As a result, English is the most frequent L2 learned globally (Eberhard et al., 2022). Whereas the use of spoken L2 is likely more relevant in social contexts, L2 reading fluency seems to be more important for an efficient functioning in formal academic, business, and other professional contexts across the lifespan. In this sense, skilled visual recognition in L2 enables learners to improve their reading comprehension, vocabulary acquisition, and written communication in their second language, as is also the case in the native language (Share, 2008a, 2008b; Share & Stanovich, 1995).

Among the many challenges that biliterates (i.e., those who can read – and not only speak – in two languages) must face are dissimilarities between L1 and L2 written codes. Reading in L2 commonly implies handling an alphabet or script that may be different from the one used in L1. Even closely related languages often use diverging sets of graphemes; for example, the Roman-based alphabets of Danish, Swedish, Icelandic, German and English – all Germanic languages – overlap, but only partially. Furthermore, some languages represent language units, such as phonemes, by written characters entirely different from the Roman alphabet used in English. The most well-known (but not the only) examples of the latter are the Greek alphabet or the different versions of Cyrillic script used in Russian, Ukrainian, Bulgarian and many other languages. In other cases, biliterates must switch to a completely different writing system when reading in English, since their L1 might involve not only a different script but also the representation of different units of the spoken language.

This article has earned badges for transparent research practices: Open Data and Open Materials. For details see the Data Availability Statement.

This is the case of Japanese Kana, for example, where written characters represent syllables rather than phonemes, or of the Chinese morpheme-based system.

Several studies have addressed the impact of L1-L2 script (dis) similarities during visual word recognition in English, both at behavioral and at neurophysiological levels (see Chung et al., 2019; Lallier & Carreiras, 2018, for reviews) showing that L2 English visual word recognition is facilitated by similarities with L1 words at phonological, orthographic, and semantic levels. Thus, several priming studies have reported a facilitation effect in English L2 word recognition when these words were preceded by phonologically and/or semantically related L1 primes written in a different script or a different writing system, such as Japanese–English (Ando et al., 2014; Hoshino et al., 2010; Nakayama et al., 2012), Korean–English (Kim & Davis, 2003), Chinese–English (Zhou et al., 2010) or Russian–English (Novitskiy et al., 2019). These cross-script priming effects converge with data from bilinguals speaking languages that share the same alphabet (Brysbaert et al., 1999; Duyck et al., 2004; Jared & Kroll, 2001; Jared & Szucs, 2002; Midgley et al., 2009; von Studnitz & Green, 2002). Similarly, research on COGNATES also shows facilitatory effects during L2 English word reading. Cognate words are (approximately equivalent) translations, which share, completely or partially, their orthography, phonology and meaning (e.g., the words *piano* and *tomaat* are examples of identical and non-identical cognates, respectively, in Dutch and English languages). Cognate L2 English words have been found to show faster processing than non-cognate words (Bultena et al., 2013; Cop et al., 2017; Peeters et al., 2013) revealing a cross-language facilitatory effect likely caused, at least in part, by an overlap in the orthography between the two languages. Importantly, these results also indicate that L1-L2 word representations may be integrated at different (orthographic, phonological, semantic) processing levels within the same bilingual lexicon and, therefore, are activated simultaneously in a non-selective manner, as proposed by, e.g., the Bilingual Interactive Activation Plus model (BIA+, Dijkstra & Van Heuven, 1998, 2002).

Nonetheless, such orthographic overlap between languages may also induce a certain degree of ambiguity given L1-L2 inconsistencies at semantic or phonological levels, leading to an interference during bilingual reading. That has been shown by some studies on interlingual HOMOGRAPHS – words that share orthography between the two languages while having L1-L2 inconsistencies in pronunciation or meaning. For instance, *sensibel* in German is written and pronounced similar to *sensible* in English but has a different meaning (*sensitive*). In a more striking ambiguity case, *cop* is an interlingual ambiguous homograph in English and Russian – while it means "policeman" and reads as /ˈkɒp/ in English, the very same graphemic representation (*cop*) means "litter" in Russian and its individual graphemes are mapped onto entirely different phonemes, being pronounced as /sor/. In fact, several graphemes in Roman English and Cyrillic scripts have the same visual form but are mapped differently onto their corresponding phonemes (e.g., "c" and "p", decoded as /k/ and /p/ in Roman but as /s/ and /r/ in Cyrillic, as in the example above). Other shared graphemes are mapped similarly in the two scripts (e.g., к, т, o, a) while yet others are script-specific (e.g., ш, ж, ч are only present in Cyrillic whereas v, q, z only in Roman). Such phonological and semantic inconsistencies across scripts have been found to increase reading latencies for L2 English words in Russian and Serbo-Croatian bilinguals with Cyrillic as L1 alphabet (Bermúdez-Margaretto et al., 2022b; Havelka & Rastle, 2005; Lukatela, 1999; Lukatela & Turvey, 1990; Rastle et al., 2009) similarly as in bilinguals with shared alphabets (Durlik et al., 2016; Libben & Titone, 2009; Macizo et al., 2010; Martín et al., 2010). According to the BIA+ model, this interference effect reflects partially overlapping homographic representations within the same multilingual lexicon whose co-activation during visual word recognition leads to competition at the sub-lexical, orthographic level (Dijkstra & Van Heuven, 1998, 2002).

Furthermore, this interference has been found to cause a higher impact during the processing of novel rather than familiar words. This is particularly important for the acquisition of written vocabulary and reading fluency in L2, which can be disrupted as a result of such L1-L2 inconsistencies. Indeed, in a recent study (Bermúdez-Margaretto et al., 2022b), the graphemic overlap across L1-L2 alphabets has been shown to slow down reading automatization and the development of orthographic representations in novel English words whereas familiar words showed significantly lower interference from L1-L2 inconsistencies. Ostensibly, the presence of well-established orthographic and semantic representations for ambiguous yet familiar L2 words compensates for the detrimental impact of L1-L2 script inconsistencies via top-down processes. Conversely, the lack of such whole-form representations for novel or unfamiliar ambiguous words leads to the necessity to process these stimuli by means of sub-lexical (letter-by-letter) bottom-up mechanisms, with the subsequent extra effort during their visual word recognition, as reflected in longer naming latencies. In agreement with this hypothesis, previous studies with monoalphabetic bilinguals reported the attenuation of such cross-lingual homographic interference by means of semantic constraints provided in sentential context (e.g., Libben & Titone, 2009). These putative compensatory mechanisms have not been properly explored at the level of their neurobiological substrate. Testing this hypothesis by means of time-resolved neuroimaging techniques would provide valuable information about their nature, by examining the visual word recognition stage when L1-L2 script inconsistencies exert their influence and interact with lexico-semantic information. Nonetheless, the question of how biliterates handle phonological L1-L2 script inconsistencies has not been directly addressed beyond behavioral measures; hence, the neurophysiological underpinnings of the putative contribution of L2 lexical knowledge and proficiency levels remain elusive.

To date, several EEG studies have successfully addressed the temporal dynamics underlying visual word recognition in both L1 and L2 reading (see Grainger & Holcomb, 2009; Midgley et al., 2009, for reviews), providing valuable information about the time course of different stages during this process and their corresponding brain correlates. It has been shown that the initial reading stages are related to low-level perceptual processing of the visual features, taking place within the first 100 ms following word presentation, and likely indexed by the N1 ERP (event-related potential). This is an early negativity of the brain signal which peaks around 90 ms post-stimulus onset at the frontal scalp sites, typically with a bipolar effect showing more positive amplitudes at occipital scalp electrodes. This ERP is sensitive to variations at the feature-level, such as letters (Carreiras et al., 2013; Madec et al., 2016b; Vergara-Martínez et al., 2020) and font (Chauncey et al., 2008; Keage et al., 2014). Therefore, it is assumed to underlie the letter identification process during the initial, sublexical visual word recognition stages (Bentin et al., 1996; Chauncey et al., 2008; Holcomb & Grainger, 2006;

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Schendan et al., 1998; Tarkiainen et al., 2002; Wong et al., 2005). Previous studies, however, did not find any modulations of this early component by script variations (e.g., Carreiras et al., 2013), indicating its sensitivity to the purely physical/visual rather than any higher-order linguistic factors. Nonetheless, different studies with mono- and bi-lingual populations have systematically registered activation of lexical and semantic information for both written and spoken words at this early latency (~30-100 ms), reflected in the N1/P1 ERP complex and sometimes even earlier (particularly in the auditory modality) in the P50 component (Assadollahi & Pulvermüller, 2003; Bermúdez-Margaretto et al., 2022a; Hauk et al., 2006; MacGregor et al., 2012; Shtyrov et al., 2014; Shtyrov & Lenzen, 2017). These findings indicate a rapid and automatic access to the lexico-semantic information through a cascaded linguistic processing. Indeed, this early modulation has been found to be sensitive to cross-script translation priming effects, reflecting a semantic facilitation of L2 words by semantically related L1 words even when presented in a different orthography (e.g., Bermúdez-Margaretto et al., 2022b; Hoshino et al., 2010).

Following the early stage, the next stimulus-specific stage might commence around 150-190 ms (Madec et al., 2012, 2016b) whereby the visual features are mapped onto the corresponding letter representations and their phonological renditions eventually result in the recognition of the whole word-form. These processes are often reflected in the P200 component modulation (as well as in N250 component, typically observed in priming studies, see for instance Chauncey et al., 2008; Holcomb & Grainger, 2006). This is a positive waveform peaking around 200 ms over fronto-central scalp sites, and it is sensitive to lexical word features, e.g., familiarity and frequency. Hence, it is typically considered as an index of the whole-form recognition (Barnea & Breznitz, 1998; Carreiras et al., 2005; Kong et al., 2010; Wu et al., 2012). Indeed, different studies have reported a modulation of this component during the training of unfamiliar or novel characters and word forms – an effect indicative of the switch from sublexical to whole-form recognition strategies through phonological recoding processes, both in monolinguals (Bermúdez-Margaretto et al., 2020; Partanen et al., 2018) and in bilinguals (Madec et al., 2016a).

Subsequently, lexico-semantic access is conventionally believed to become fully-fledged between 350-500 ms, a process typically reflected in the modulation of the N400 component, a negative deflection peaking around 400 ms post-stimulus onset over centro-parietal scalp sites (Kutas & Federmeier, 2011). This component is sensitive to both lexical and semantic word features, with higher N400 amplitudes reflecting difficulties in processing and word integration. As such, the N400 is considered a robust neural correlate of (effortful) lexico-semantic processing, although lexical and semantic information access can already commence at earlier latencies, as described above. Existing bilingual studies have consistently reported the reduction of the N400 response in cross-linguistic priming tasks – a pattern indicative of the facilitation in the processing of L2 English targets preceded by semantically related L1 primes, both within the same alphabet (Kerkhofs et al., 2006) and among readers of different L1-L2 scripts (Hoshino & Thierry, 2012; Jouravlev & Jared, 2014; Novitskiy et al., 2019). For instance, Novitskiy et al. (2019) found a N400 facilitatory cross-script priming effect for L2 English target words primed by phonologically related masked L1 words presented in Russian Cyrillic script, indicating the semantic and phonological interplay between L1 and L2 scripts in Russian–English biliterates. It is unclear, however, whether shared L1-L2 orthography would lead to the interference rather than facilitation during L2 reading processes, and if that can be differently reflected at early (~200 ms) and late (~400 ms) orthographic and semantic stages depending on the quality of L2 word representations.

Therefore, the aim of the present EEG study is to fill this gap by investigating the time course of the processing of L2 familiar and novel words in ambiguous script conditions. Given its high temporal resolution, the EEG technique appears most optimal for determining the stage(s) within the visual word recognition process at which the L1-L2 script interference (and its putative compensation via top-down mechanisms) takes place. Considering previous findings, we put forward the following hypotheses about the influence of L1-L2 script inconsistencies at different stages of visual word recognition. First, we did not expect to observe either such script inconsistencies or their (putative) interactions with lexico-semantic information via top-down mechanisms to be reflected in the brain signal within the 200 ms after stimulus onset, given that early components are typically considered by the majority of researchers as sensitive to low-level visual variations and not affected by script variations (e.g., Carreiras et al., 2013). Nonetheless, considering the cascade nature of visual word recognition processes, with high-level lexico-semantic processes taking place relatively early (already before 200 ms), it might be that lexical differences between words and pseudowords would be captured at such early latencies regardless of their script. Second, we expected the L1-L2 script interference as well as its interaction with lexico-semantic information to manifest at later processing stages (from 200 ms onwards) relative to word-form and semantic access and indexed in P200 and N400 components, with more salient interference effects for novel than for familiar words, as these ERPs have previously shown to reflect top-down processes through the activation of lexical information (Carreiras et al., 2009; Dunabeitia et al., 2009).

Materials and Methods

Participants

Twenty-four speakers of Russian as L1 and English as L2 (mean age=22.70, SD=3.78, range= 18-35; 18 females) were recruited for participation in this study. All were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971; mean score=87.5, SD=18.5, range=44-100) with normal or corrected-to-normal vision and no history of neurological or psychiatric disorders. All participants were biliterates (L1 Cyrillic Russian and L2 Roman English) with different levels of L2 proficiency, literacy and age-of-acquisition onset (see Table 1). Participants' biliteracy was assessed by means of both subjective (through an abridged version of LEAP Questionnaire; Marian et al., 2007) and objective measures (through the Cambridge English Test for General English Proficiency, and English picture naming task; see details in the procedure section below). The study was approved by the Ethics Committee of the Department of Psychology, HSE University.

Stimuli

Experimental materials consisted of 12 words and 12 pseudowords equally divided into unambiguous L1 Cyrillic (4 words, e.g., "*шаг*", and 4 pseudowords, e.g., "*шаз*"), unambiguous L2 Roman (4 words, e.g., "*vet*", and 4 pseudowords, e.g., "*vaz*")

Table 1 Participants' second language (English) reading proficiency evaluation obtained by means of LEAP-Q Questionnaire and Cambridge Test

LEAP-Q for L2 reading experience and proficiency		
	Mean	*SD, range*
L2 reading proficiency (0-10)	6.05	1.85, 7
L2 reading exposure (0-10)	4.40	2.37, 9
Years of formal study of English	9.20	4.55, 15
Age of L2 reading Acquisition	10.85	3.83, 16
Age of L2 reading fluency onset	14.21	3.98, 15
Years immerse in L2 reading environment		
Country	0.06	0.14, 0.5
Family	0	0, 0
School/Work	1.53	3.02, 11
Cambridge Test for L2 reading comprehension		
	Mean	*SD, range*
	11.92	5.18, 19

and ambiguous script conditions (4 words, e.g., "*cop*", and 4 pseudowords, e.g., "*pex*"). All stimuli were 3 letters in length with a Consonant-Vowel-Consonant (CVC) structure. Given the tight restrictions on stimulus properties (script, familiarity, structure, etc.), a relatively limited set of items (24 in total) was selected for the study. This allowed for an effective manipulation of the phonological ambiguity, while ensuring a strict control of other variables such as bigram frequency and length. To ensure maximal similarity across stimuli, pseudowords were designed maintaining the first letter of a familiar word in the corresponding script condition. Moreover, stimuli presented in L1, L2 and ambiguous conditions were matched across each group of familiar words and pseudowords for their log trigram frequencies (comparisons carried out using nonparametric U Mann-Whitney-tests confirmed no differences across conditions, all contrasts $p>.1$). Trigram values for L1 and L2 stimuli were taken from Russian National corpus (http://www.ruscorpora.ru/new/search-main.html) and British National Corpus (https://www.english-corpora.org/bnc/) online databases, respectively, and log transformation was applied in order to normalize both datasets. See Appendix 1 for the full list of stimuli.

The stimuli in the unambiguous script condition included graphemes unique to each alphabet (e.g., *j, ш*) as well as those that are common in both languages and mapped onto the same phonemes i.e., phonologically consistent across scripts (e.g., *a, м*). In contrast, the ambiguous script stimuli were created by combining common and consistent graphemes with common but inconsistent graphemes – namely, those used in both Cyrillic and Roman alphabets but decoded into a different sound depending on the script (i.e., the grapheme "*n*" is decoded as /n/ in Roman but as /p/ in Cyrillic, and the written English word "*nap*" reads as /par/ in Russian and means "steam"). To ensure the stimulus ambiguity in the ambiguous condition, a combination of handwriting fonts ("Notperfect regular" and "Swanky and Moo Moo Cyrillic") was used since they provide a larger choice of overlapping graphemes (see Appendix 1).

An additional set of stimuli was selected for the use during an L2 picture naming task designed to assess participant's objective English proficiency. To this end, a set of 90 black-and-white pictures equally divided between high (30), medium (30), and low (30) familiarity conditions were extracted from the Snodgrass & Vanderwart image database (Snodgrass & Vanderwart, 1980). These were matched across familiarity conditions for the age of acquisition, name agreement, and visual complexity (all $p>0.05$). See Appendix 2 for the full list of stimuli used as well as their IDs in the Snodgrass & Vanderwart database.

Procedure

After giving their written informed consent, participants were seated in a comfortable chair inside an acoustically and electromagnetically shielded EEG booth (Infomed Ltd, Moscow, Russia). Then, they undertook the tests assessing their biliteracy level. First, in order to obtain L2 reading comprehension scores and ensure reading ability in English, participants completed the Cambridge English Test for General English Proficiency (online version, https://www.cambridgeenglish.org/test-your-english/general-english/). Second, a short version of the Leap Questionnaire was used, including those questions particularly related to L2 reading skills (Marian et al., 2007). A minimum level of L2 biliteracy (at least 15 points on the general scale for L2 proficiency) was required to continue to take part in the study, ensuring at least low-to-medium L2 reading skills. See Table 1 for the detailed results of the biliteracy assessment. Third, the EEG preparation procedure followed (see next section for details), after which participants completed the Edinburgh Handedness Inventory (Oldfield, 1971), and received main experimental instructions. Participants were asked to read aloud the stimuli presented at the center of the screen as fast and as accurately as possible. Importantly, they were told that both familiar and novel (pseudowords) stimuli would be presented either in their L1 (Russian Cyrillic) or L2 (English Roman) languages, whereas no specific instruction was given as to which language they should use to name the stimuli during the task.

While participants' EEG signal was being recorded, they were presented visually with a set of 24 words and pseudowords in a single-word reading task. All items, which they had to read aloud, were presented pseudorandomly 10 times across 10 repetition sub-blocks (each randomized anew) in handwriting black font over a grey background by means of E-Prime 2.0 Professional software (Psychology Software Tools, Inc., Pittsburgh, PA; Schneider et al., 2002). See Figure 1 for the details of the experimental sequence. The presentation of the stimuli was pseudorandomized within each subblock and for each participant, with a requirement of no two consecutive stimuli belonging to the same condition. Moreover, given that the previous presentation of an L1 or L2 stimulus could bias the pronunciation of an ambiguous stimulus, all verbal trials were interleaved with a non-linguistic task using distractor target stimuli (white and black diamond shapes; see Figure 1). Participants had to indicate the color of the diamond (black or white) by pressing the corresponding right (L) or left (D) keyboard key. The response keys were labeled with color stickers (to avoid verbal naming). The color of distractor stimuli was randomized across trials and responses were counterbalanced across participants (namely, half of them responded to white color with their right index finger and to black with their left index finger whereas the other half did the opposite). Such an inter-trial non-

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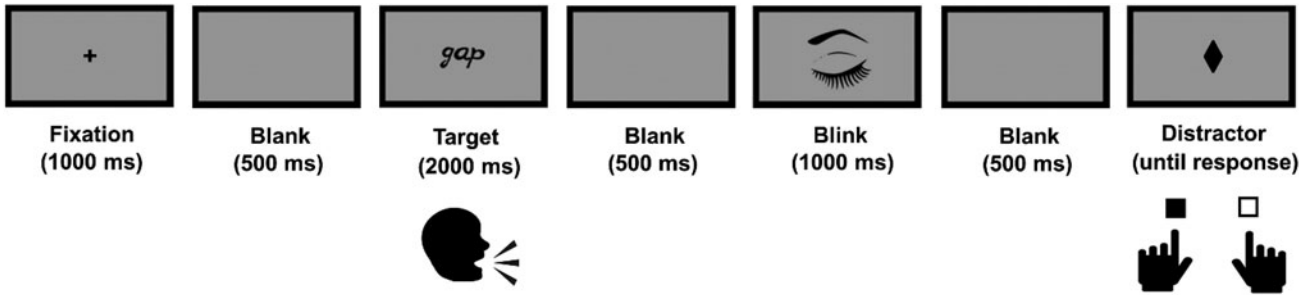

Figure 1. Schematic diagram of a single trial during the reading task
Note. For each trial, target words and pseudowords were followed by a blink instruction and a distractor non-verbal target detection task, intended to prevent the bias in the pronunciation of ambiguous stimuli. Participants had to decide the color of a geometrical figure by pressing the corresponding key on the keyboard. The color of distractor stimuli was randomized across trials and responses were counterbalanced across participants. EEG signal was continuously recorded during the task. (NB: The verbal stimulus *gap* in this example is ambiguous, being read as /dar/ in Cyrillic script and meaning 'gift' in Russian.)

linguistic distractor task (target color categorization) was introduced to prompt participants to disengage from the reading processes, thereby preventing or at least minimizing the influence of the preceding stimulus script on the language selected to read the next stimulus (as suggested by previous studies using cross-linguistic naming; e.g., Bermúdez-Margaretto et al., 2022b; Reverberi et al., 2018), which is particularly important for the ambiguous items. Before starting the reading task, participants were presented with 12 practice trials (2 trials per condition) using similar (but not identical) stimuli to those presented in the main experiment. To minimize fatigue, participants were given two short breaks (after 4th and 7th subblocks). Vocalizations produced during the task were recorded by means of a SVEN MK-150 microphone (SVEN Scandinavia Ltd, Kotka, Finland) attached near the participant's mouth. To minimize EEG contamination, participants were instructed to avoid any unnecessary movement during the task and to blink only when instructed (via a picture of an eye on the screen, see Figure 1).

Immediately after the main reading task, participants underwent an L2 picture naming task where they had to name the pictures presented in English – aloud and as fast and accurately as possible using English words – as another test of their L2 proficiency. The pictures were displayed in the center of the screen by means of E-prime software, in black line drawings over a white background. To this end, a 500 ms fixation cross appeared in the center of the screen, followed by the picture display for 2000 ms. Stimulus presentation was randomized across participants. Participant's vocalizations in each trial were recorded by means of the same microphone as in the reading task. The duration of the entire experiment was approximately one hour, excluding the EEG preparation time.

EEG recoding and preprocessing

EEG signal was recorded during the reading task by means of 64 Ag/Cl active electrodes (actiCap, Brain Products GmbH, Gilching, Germany), amplified and digitized at 1000 Hz sampling rate with an ActiChAmp amplifier (Brain Products GmbH). Ocular activity was recorded by two electrodes placed at the external and infraorbital canthus of the left eye. An additional analog channel was used to feed the EEG amplifier with the input signals recorded by the sound sensor of the microphone, thus allowing the detection of the onset of participant's utterances during EEG recording. The electrode placed at the vertex (Cz electrode) served as reference; and high and low pass filters at 0.1 Hz and 100 Hz, respectively, were applied.

The preprocessing of the EEG signal was carried out in Brainstorm software version 04-Jun-2019 (Tadel et al., 2011) within Matlab version R2017b (MathWorks Inc, Natick, MA) environment. The preprocessing steps were as follows. First, the signal was filtered by a 45-Hz low-pass filter. Second, an Independent Component Analysis (ICA) was carried out in order to detect and remove any ocular artifacts (average number of rejected ICA components= 3, range= 1-6). Third, data were referenced to the averaged mastoid activity and epoched into segments from 200 ms pre- to 800 ms post-stimulus onset; a baseline correction was applied using the 200 ms pre-stimulus interval. Then, an artifact rejection (using exclusion criteria at ± 100 μV) procedure was applied to remove epochs containing artifacts or naming responses earlier than 400 ms stimulus onset according to triggers sent by the sound sensor (the mean number of rejected trials per condition was: L1 words= 3, representing 6.25% of the data; L2 words= 3, 6.88% of the data; ambiguous words= 2, 5.42% of the data; L1 pseudowords= 2, representing 6.04% of the data; L2 pseudowords= 3, 6.25% of the data; ambiguous pseudowords= 2, 5.94% of the data; no significant differences between conditions). For visualization purposes, EEG epochs relative to the visual stimuli onset were averaged per participant and per condition (words and pseudowords in L1, L2 and ambiguous scripts) and the ERPs were computed according to conventional practices in the ERP field, whereas the actual data analysis (see below) was single trial-based (average number of included trials per condition for visualization purposes: L1 words= 38, range=30-40, SD=2.56; L2 words= 37, range=30-40, SD=2.50; ambiguous words= 38, range=32-40, SD=2.49; L1 pseudowords= 38, range=31-40, SD=2.37; L2 pseudowords= 38, range=30-40, SD=2.48; ambiguous pseudowords= 38, range=32-40, SD=2.57; no significant differences between conditions).

Data analyses

For the behavioral data analysis, naming latencies obtained during the reading task were extracted for each trial and each participant using Praat software 5.2.01 (Boersma, 2006). Utterances containing errors or latencies 2 SD above or below the mean were excluded from further analyses. Responses to the ambiguous stimuli were considered equally correct if read in Russian or English, but not if they mixed both alphabets within a single utterance.

For the ERP data, a visual inspection of the ERP waveforms computed for words and pseudowords across all script conditions was carried out in order to determine the time windows of the

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effects of interest – namely, those related to early and late lexical and semantic access (i.e., P1/P50, P200 and N400 components). Three time ranges were identified and selected (30–70 ms, 190–215 ms and 350–400 ms), in line with latencies typically observed for these components in previous studies (e.g., Bermúdez-Margaretto et al., 2020, 2022a; Kerkhofs et al., 2006; MacGregor et al., 2012). Nonetheless, in order to further confirm reliable effects in the time windows identified via visual inspection, permutation tests using threshold-free cluster enhancement method (TFCE: Smith & Nichols, 2009) were carried out using MNE-Python software (Gramfort et al., 2013, version is 1.5.1), in which differences between words and pseudowords were examined across all sensors and time points – separately for each script condition (N permutations = 1000). This data-driven procedure allowed us to detect significant clusters reflecting lexicality effects across the whole ERP segment (in this case, -200 to 1000 ms) while controlling for multiple comparisons by taking the maximum statistic over all spatiotemporal data points.

TFCE analyses identified significant lexicality effects in three distinct time windows (centered around 50, 200 and 370 ms), consistently with those observed in the visual inspection and compatible with the modulation of P1, P200 and N400 components. Specifically, a lexicality effect was found for each script condition around 50 ms at posterior channels (peaking at 42 ms in the L1 script condition, at 58 ms in L2 script condition and at 53ms in the ambiguous condition). In addition, analysis in L1 and L2 conditions identified a lexicality effect peaking at 206 ms at a frontocentral scalp region and a lexicality effect at 376 ms at centroposterior region, respectively for each script condition (please see Supplementary Figures 1-3 for visualization of the effects). Further trial-by-trial analysis via Linear Mixed-Effect Models (LMMs) was performed for the ERP data averaged for each condition in the time windows and scalp regions identified in the previous steps. In particular, ERP amplitudes were averaged at a centroposterior region (including CPZ/1/2/3/4, PZ/1/2/3/4 channels) for the 30-70 and 350-400 ms time windows, and at frontocentral region (including FZ/1/2/3/4, FCZ/1/2/3/4 channels) for the 190-215 ms time window.

Naming latencies and ERP responses obtained for each condition across block exposures were analyzed by means of LMMs computed in R (R Core Team, 2022) and using the *lme4* package 1.1.31 (Bates et al., 2014). The models included Script (L1 vs. L2 vs. Ambiguous), Lexicality (words vs. pseudowords), Cambridge proficiency (individual scores), accuracy in picture L2 naming (individual scores), and their interactions as fixed factors. The model incorporated random effect structure including by-participant and by-item intercepts (in the case of ERP data, trial-level intercepts). Our approach adhered to the guidelines presented by Scandola and Tidoni (2021), who advocated the implementation of Complex Random Intercepts (CRI) to strike an optimal balance between maximally specifying random effects, convergence, and computational efficiency in random-effects specification and model selection. In the context of a full-CRI model, complex random slopes were replaced by different random intercepts for each grouping factor, effectively mitigating the risk of Type-I error. In each analysis iteration, we initially fitted a maximal model; if convergence was not achieved, we systematically removed the CRI component explaining the least variance and reattempted model fitting until convergence was achieved. Additionally, we subjected the convergent model to further scrutiny, including the assessment of key assumptions such as the normality of residuals' distribution and homoscedasticity.

The *hypr* package 0.2.3 (Rabe et al., 2020) was used to perform sequential difference contrasts for categorical variables (2-level predictor Lexicality: 1/2, -1/2, and 3-level predictor Script: − 2/3, 1/3, 1/3). Block (exposures 1 to 10) was encoded with sum contrast coding and included in models as a covariate. The models were fitted based on the Kenward-Roger Approximation, which provides more conservative t-values, especially in cases where the models are built upon a relatively limited number of observations. For the model summaries, the estimate of the contrast coefficient with absolute *t* values larger than 1.96 was considered as being indicative of a 'precise' estimate (Baayen et al., 2008). The data, code, and experimental materials necessary to reproduce the present study are freely available at https: https://osf.io/qb6fz/?view_only=928a22bfdaec432998a6f7d85a413386.

Results

Behavioral analysis

Behavioral data from two participants were removed due to a technical error during voice recording, and two more participants' data were removed due to missing L2 proficiency scores that could be used as a predictor of naming latencies, leaving a set of 20 participants and 4798 observations after trimming procedures (722 observations, 13.1% discarded due to missing responses, and 121 observations, 2.5% discarded due to deviations from the range of ± 2.5 standardized residual errors). Supplementary Figure 4 shows averaged naming latencies obtained for words and pseudowords presented in the L1, L2 and ambiguous script conditions across block exposures. LMMs revealed statistically reliable main effects of Script, indicating faster naming latencies for stimuli presented in L1 than in L2 (β=0.085, t=2.1) or ambiguous scripts (β=−0.086, t=−2.1), Lexicality (β=0.074, t=2.3), since familiar words exhibited faster naming latencies than pseudowords, and Block, with naming latencies decreasing across exposures particularly from first to second (β=0.089, t=10), third (β=0.67, t=7.6) and fourth exposure (β=0.024, t=2.7), although an opposite trend was found in the ninth (β=−0.05, t=−5.6) and tenth exposures (β=−0.055, t=−6.2) where naming latencies increased. Furthermore, L2 Proficiency scores obtained via Cambridge test were also found significant (β=−0.059, t=−2.7). No other main effects or their interactions were found significant. A summary of model fit for the analysis of naming latencies can be seen in Supplementary Table S1.

ERP results

Data from two participants were removed from the analysis due to missing proficiency values in the L2 picture naming task that could be used as predictor of the ERP modulation, leaving a dataset of 22 participants for further analyses. A total of 4961 observations out of 5280 data points were considered for LMMs analyses after discarding trials in the artifact rejection procedure (319 observations, 6.04% of rejection). Summary of the model fit for ERP data in each time window analyzed can be seen in Supplementary Tables S2, S3 and S4. LMMs analysis carried out in the early time window from 30 to 70 ms revealed significant differences between the amplitude exhibited by words and pseudowords regardless of the alphabet of presentation (Lexicality, β=0.46, t=2.1), which importantly, were found to be modulated by L2 proficiency expressed in the performance of the Cambridge test (i.e., Lexicality x L2 proficiency-Cambridge

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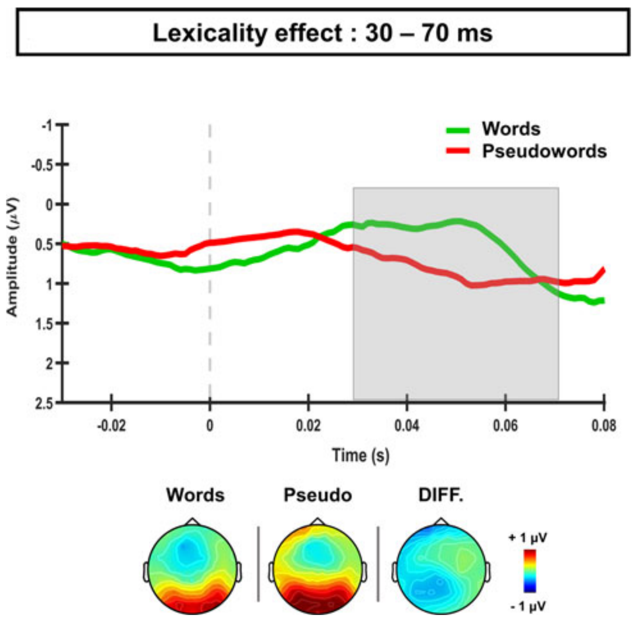

Figure 2. Lexicality effect at 30–70 ms
Note. Upper panel. ERP waveforms for words and pseudowords (channels selected over the centroposterior region). The grey shaded area highlights the time window (30–70 ms) analyzed in which Lexicality effect was found significant. *Lower panel*. Topographic maps showing the scalp distribution of the ERP activity elicited by words and pseudowords, as well as for their difference, at this early latency.

interaction, β=0.66, *t*=2.5). See Figure 2 for visualization of the lexicality effect in the 30-70 ms time window.

More specifically, Lexicality x Proficiency interaction revealed that familiar words exhibited more negative amplitudes than unfamiliar pseudowords especially in the highest levels of L2 proficiency whereas no lexicality effect was found at the lowest L2 proficiency levels. See Supplementary Figure 5 (upper panel). Interestingly, no main effects or interactions involving the Script factor were detected at this latency.

Regarding the P200 time window (190–215 ms), LMMs revealed a significant interaction between Lexicality and Script (β=1.7, t=2.2), indicating that, whereas no script effect was found for pseudowords, familiar words presented in ambiguous alphabet exhibited more positive amplitudes than those presented in L1 script; a similar trend although not reaching significance was found for L2 words showing higher P200 amplitudes than those presented in L1 script, whereas no differences were observed between ambiguous and L2 scripts. See Figure 3.

Moreover, our analysis also revealed a significant modulation of L2 proficiency in the impact of the script (significant interaction between Script and L2 proficiency exhibited in accuracy picture naming, β=−1.2, t=−2.6), indicating that differences between stimuli presented in L1 alphabet and L2 and ambiguous scripts increased at lower levels of L2 proficiency. See Supplementary Figure 5 (middle panel). No other main effects or interactions exceeded the threshold of absolute *t* values larger than 1.96.

LMMs analysis carried out for the ERP data in the N400 time window (350–400 ms) showed a significant Script effect (β=0.94, t=2.5), indicating differences between stimuli presented in L1 and L2 alphabets, with more positive amplitudes for those in non-native L2 script. The effect of stimuli repetition across the task was also found significant, with an increasing positivity in the second exposure (i.e., block effect in second block, β=−0.91, t=2.4) and a reducing positivity afterwards (i.e., block effect in sixth repetition, β=1.1, t=2.9). Furthermore, a significant interaction between Lexicality and Script was also found (β=−2, t=−3.2, see Figure 4). Thus, ambiguous pseudowords exhibited less positive-going amplitudes than L1 and L2 pseudowords, which did not show differences. For words, on the contrary, script differences were more salient between L2 and both L1 and ambiguous conditions, the latter of which did not differ in their N400 amplitudes.

More importantly, an interaction between Script, Lexicality and L2 Proficiency was also reliable in the analysis. This interaction revealed that the influence of the script effect in the N400 modulation differed between words and pseudowords as a function of the proficiency expressed in the accuracy in L2 picture naming (β=−1.8 t=−2.8). For pseudowords, L2 proficiency only modulated the N400 amplitude exhibited by ambiguous pseudowords, with higher impact of the script ambiguity manifested in lower L2 proficiency levels and reflected in less positive N400 amplitudes; conversely, L2 proficiency tended to modulate N400 amplitudes exhibited by words in all script conditions although this modulation was more pronounced for L1 words, indicating the influence of L2 proficiency also on the processing of the native language. See Supplementary Figure 5 (lower panel).

Discussion

The present study addressed the neurophysiological mechanisms underlying the processing of L1-L2 script inconsistencies in biliterates, fluent users of Roman-based English and Cyrillic-based Russian alphabets. Crucially, the two scripts, although originally derived from the same common ancestor (ancient Greek), partially overlap in a peculiar way, with some shared graphemes decoded into similar phonemes, others that share visual form but diverge phonologically, and some that are only present in one but not in the other alphabet. Using these unique properties, we explored behavioral and neurophysiological effects of such inconsistencies, their detrimental influence on reading and its putative attenuation through top-down processes. Phonological L1-L2 incongruencies were hypothesized to interfere differently with L2 reading process depending on the activation of lexico-semantic information, thus being more salient for novel than for familiar words. Such differential script interference was expected to affect orthographic and semantic stages of visual word recognition, potentially modulating early (~200 ms) and late (~400 ms) brain responses. Our data revealed that L1-L2 script ambiguity does modulate P200 and N400 responses differently depending on the available lexico-semantic information and L2 proficiency, thus confirming the existence of a compensatory top-down mechanism particularly important at the early stages of the whole-word recognition processes. In what follows, we offer a brief discussion of these findings as well as their importance for the current theories of bilingualism.

The interference caused in word reading as a consequence of L1-L2 script inconsistencies was directly observed in the modulation of the N400 component, with less positive responses for novel words presented in ambiguous than in L1 or L2 consistent scripts conditions. According to existing literature (e.g., Kutas & Federmeier, 2011), such an N400 response enhancement indicates a more effortful processing, likely as a consequence of shared L1-L2 graphemes inconsistently decoded across the two alphabets, leading to a grapheme-to-phoneme resolution conflict.

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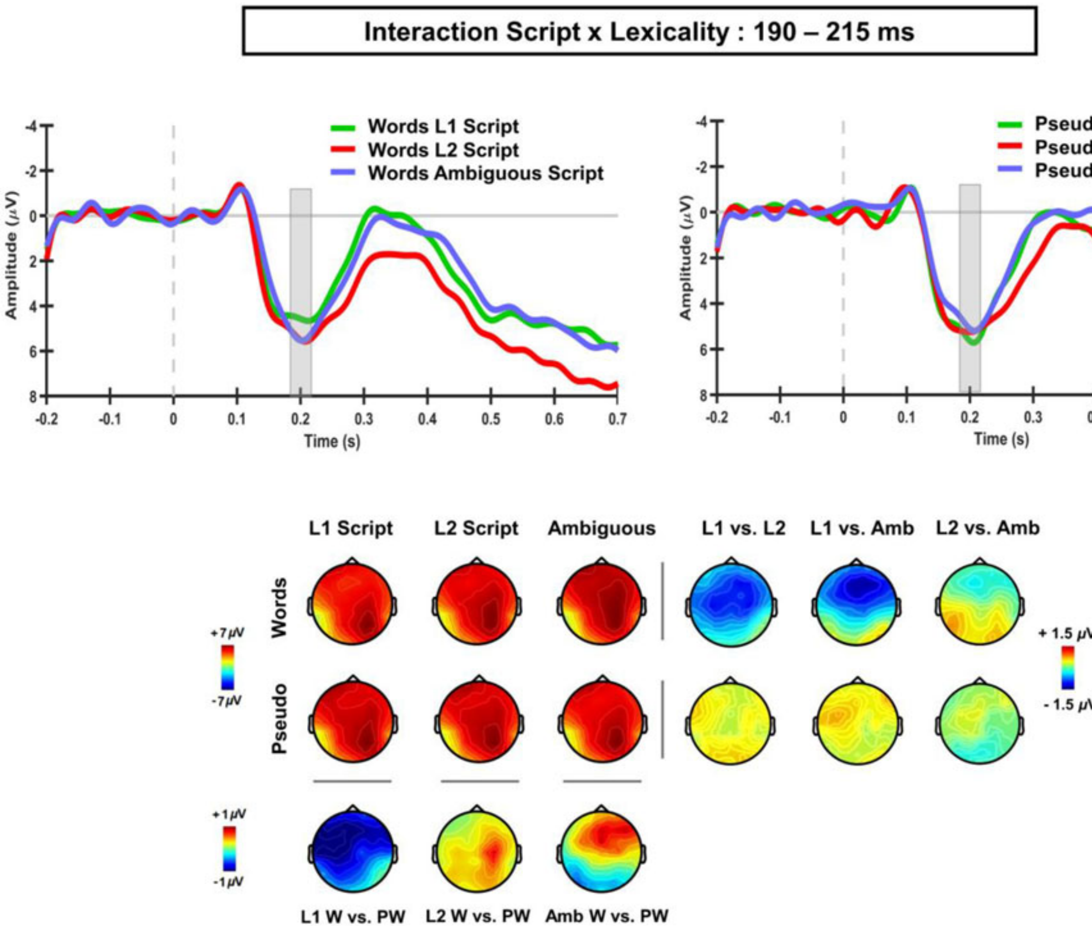

Figure 3. Script x Lexicality interaction effect at 190–215 ms

Note. Upper panel. ERP waveforms for words and pseudowords presented in L1, L2 and ambiguous script (channels selected over the fronto-central region analyzed). The grey shaded area highlights the time window (190–215 ms) for the significant interaction between Lexicality and Script factors. *Lower panel*. Topographic maps showing the scalp distribution of the ERP activity elicited for each condition in the 190–215 ms time window as well as the scalp distribution of the differences between conditions at this latency.

Importantly, this effect contrasts with the pattern exhibited by familiar words, for which no N400 differences were found between ambiguous and L1 scripts, indicating similar-to-native lexico-semantic processing of L2 words in conditions of script inconsistency. Such an advantage for familiar over novel stimuli is likely supported by the activation of the word-specific information at lexico-semantic level, which in the case of pseudowords is absent due to their lack of an integrated mental representation. Moreover, this N400 functional dissociation between words and pseudowords agrees with the existing ERP data reporting effects indicative of a lexical-semantic feedback during the orthographic processing, as reflected in both early (N250) and late (N400) responses (Gutierrez-Sigut et al., 2019; Vergara-Martínez et al., 2015). For instance, Vergara-Martínez et al. (2015) found a higher N400 response for pseudowords than for words using a matched-case identity priming task, indicating that the orthographic processing level is modulated by the lexical one. These findings support fully interactive models of visual-word identification (see Carreiras et al., 2014, for a review). Indeed, the present study shows that such lexico-semantic activation unfolds following a rather automatic and cascaded processing during visual word recognition, as reflected in the earlier brain responses modulated selectively for lexical stimuli at ∼50 and 200 ms, as well as those registered later on, around 400 ms.

In this line, the present study reports ERP patterns indicative of lexical activation during biliterate reading as early as 30-70 ms following word onset; in particular, lexico-semantic information was automatically accessed at this latency regardless of the script, with higher, more negative amplitudes exhibited for words than for pseudowords (which were, importantly, matched for other psycholinguistic properties, such as bigram frequency and length). This effect is consistent with a body of previous E/MEG research suggesting an extremely rapid and automatic access to the lexico-semantic information both in spoken (MacGregor et al., 2012; Shtyrov et al., 2014; Shtyrov & Lenzen, 2017) and visual (Assadollahi & Pulvermüller, 2003; Bermúdez-Margaretto et al., 2022a; Hauk et al., 2006; Hoshino et al., 2010; Shtyrov & MacGregor, 2016) domains. Importantly, the pattern of lexico-semantic brain responses found in the present study is fully congruent with a recent proposal of a dual mechanism for semantic access during visual word recognition (Sulpizio et al., 2022), with an initial (∼100 ms or even earlier) process that allows for a coarse semantic analysis of the lexical status of the word, followed by a fine-grained analysis typically indexed in the modulation of N400. Indeed, the early 30-70 ms effect did not differentiate between L1 and L2 stimuli, implying similar processes of automatic lexical activation to all items in a bilingual's lexicon. The latter suggestion is corroborated by a similar latency of a

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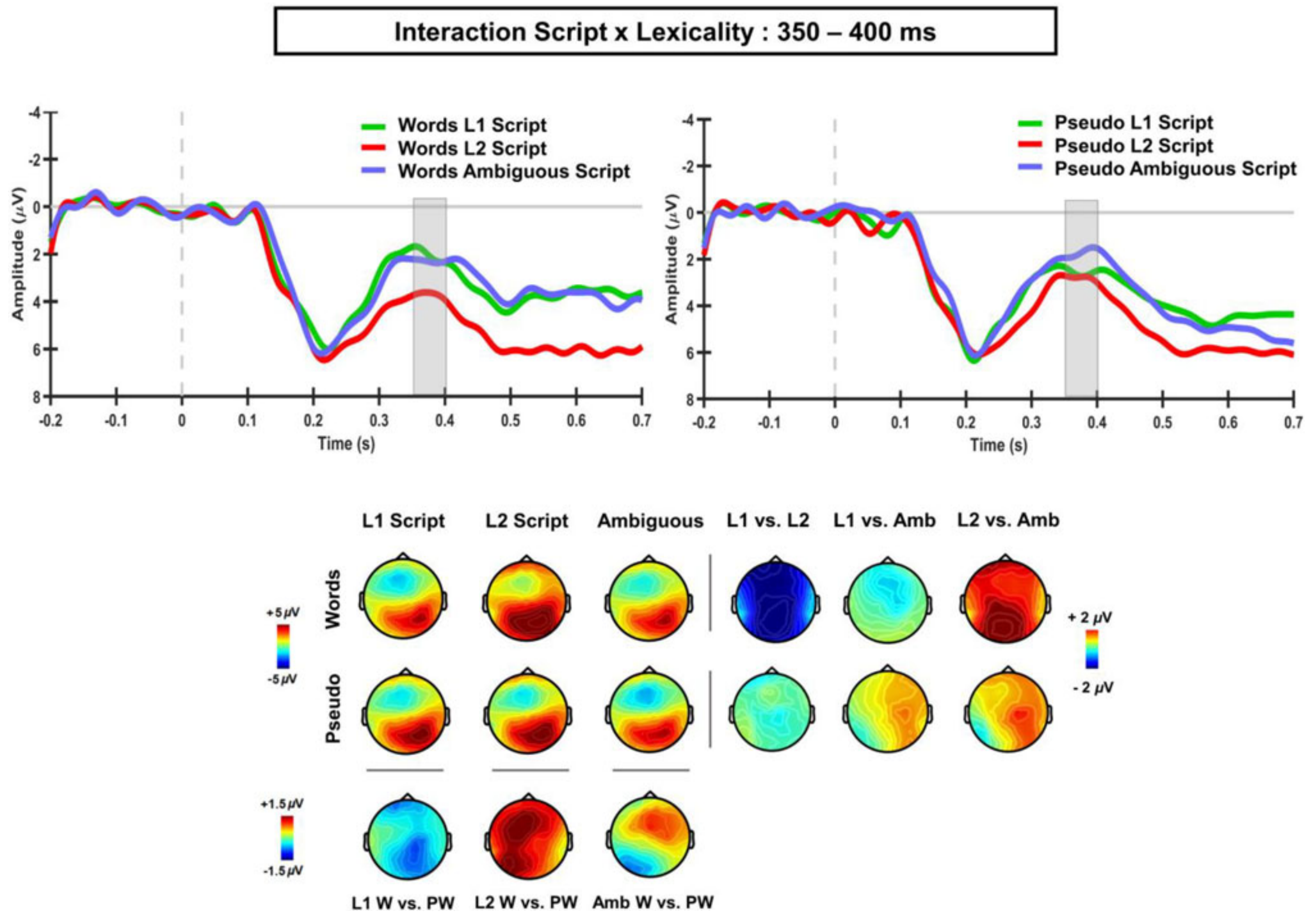

Figure 4. Script x Lexicality interaction effect at 350–400 ms

Note. Upper panel. ERP waveforms for words and pseudowords presented in L1, L2 and an ambiguous script (channels selected over the centroposterior region). The grey shaded area highlights the time window (350–400 ms) for the significant interaction between Lexicality and Script factors. *Lower panel*. Topographic maps showing the scalp distribution of the ERP activity elicited by each condition in the 350–400 ms time window as well as the scalp distribution of the differences between conditions at this latency.

semantic cross-linguistic interaction in a recent masked priming ERP study (Bermúdez-Margaretto et al., 2022a). Instead, L1-L2 script inconsistencies were detected at a subsequent stage related to orthographic analysis, in which familiar L2 words in both ambiguous and non-ambiguous condition exhibited, in comparison to those presented in L1, a positivity enhancement around 200 ms. This effect, absent for unfamiliar words, is compatible with the modulation of the P200 component, suggesting a higher engagement of whole-word visual recognition strategy for these stimuli (Barnea & Breznitz, 1998; Carreiras et al., 2005; Kong et al., 2010; Wu et al., 2012). Hence the access to orthographic representations is shown as a preferred reading strategy for these words whereby the use of a sub-lexical grapheme-to-phoneme decoding is hindered either by non-native or inconsistent decoding processes. Similar enhancements of early ERPs underpinned by a boost to top-down processes have been recently reported for difficult-to-read stimuli (Vergara-Martínez et al., 2021).

Therefore, the neural responses obtained for words and pseudowords in our study reveal a different impact of L1-L2 orthographic overlap during L2 reading as a function of availability of lexico-semantic information. Such impact was clearly observed for unfamiliar stimuli in the N400 response, whereas this interference was attenuated likely via a top-down activation of lexico-semantic traces for familiar words, as indicated by both early ERP effects. These findings support existing behavioral data showing the interference of L1-L2 alphabet inconsistencies in biliterate visual word recognition (Bermúdez-Margaretto et al., 2022b; Havelka & Rastle, 2005; Lukatela, 1999; Lukatela & Turvey, 1990; Rastle et al., 2009). Nonetheless, naming latencies reported in the present study did not show such differential impact of script ambiguity for lexical and non-lexical stimuli at statistically significant levels. Considering that the present study strictly followed the paradigm from a previous experiment where such an effect was significant (Bermúdez-Margaretto et al., 2022b), this inconsistency may be due to a different sample size (22 participants, whereas the previous purely behavioral experiment involved a considerably larger sample of 50 participants, typically not attainable in more resource-demanding EEG studies), although the exact reasons for this should still be addressed in future studies. Importantly, the present ERP study extends previous behavioral findings by providing information regarding the exact time-course and the neural compensation mechanisms of such interference.

Importantly, our findings are consistent with the predictions of the BIA+ model, which suggests that the processing of homographic words with shared L1-L2 orthography would involve a competition for the activation and corresponding phonological recoding access at sublexical, orthographic stages during visual

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recognition (Dijkstra & Van Heuven, 1998, 2002). In this sense, the ambiguous script effect was indexed by the modulation of the P200 response, related to orthographic word-form access, with those familiar words consisting of competing L1-L2 graphemes showing the enhancement of this component. Crucially, our data suggest that, for familiar stimuli, competing activation led by L1-L2 script inconsistencies is likely resolved at this early processing stage with the help of a whole-word visual recognition of these stimuli, driven by well-established orthographic representations. This top-down compensatory mechanism, that seems to reduce the impact of cross-alphabetic incongruencies during L2 reading (as reflected in reduced N400 responses), might be indeed triggered by the earlier (~30 ms) and automatic activation of lexico-semantic information for these stimuli. Conversely, the present data indicate that for unfamiliar L2 words such a script inconsistency was only detected at a later, post-lexical stage, in the absence of any specific mental representations for these stimuli that could prompt a top-down compensatory mechanism. In agreement with this idea, our data revealed the significant modulation of L2 lexical knowledge, reflected by participants' performance in the Cambridge test and in the L2 picture naming task, in the lexical access and subsequent impact of the L1-L2 script inconsistencies during reading. In particular, the higher L2 proficiency and hence the more efficient access of the L2 lexico-semantic representations are, the stronger the facilitation in such early and automatic lexical access (reflected in more negative responses at 30 ms), and the lower the impact of the cross-script inconsistencies (reflected in higher P200 and reduced N400 amplitudes) becomes. This confirms the crucial role of the lexico-semantic access in the compensation of L1-L2 script inconsistencies. Interestingly, the strongest modulation of L2 proficiency was observed in the N400 amplitudes for L1 words, whereas for pseudowords such a modulation was mainly observed in ambiguous condition. Such differential pattern indicates the crucial role of L2 proficiency in resolving L1-L2 inconsistencies particularly for novel words with no mental representation, whereas for those accessible in the mental lexicon (and hence less influenced by script inconsistency) L2 proficiency was particularly beneficial for words in L1 condition. Similar beneficial effects of bilingualism for the processing of native language were reported at cognitive (Blumenfeld & Marian, 2013; Soliman, 2014) and linguistic (Abu-Rabia & Sanitsky, 2010; Antoniou et al., 2015; Kaushanskaya & Marian, 2009) levels of analysis; they are often framed as BILINGUAL ADVANTAGE effects (Bialystok, 1999, 2017; Friedman, 2016). In this line, the facilitatory effects observed in our study with regard to facilitated L1 lexico-semantic processing as a consequence of L2 experience support previous findings of better reading and orthographic learning abilities in biliterates in comparison to monoalphabetic bilinguals, an effect likely due to a higher flexibility of the former group's orthographic systems (Kahn-Horwitz et al., 2014; Modirkhamene, 2006; Schwartz et al., 2007, 2014).

Overall, our data elucidate a key role of L2 proficiency in the compensation of L1-L2 script inconsistencies during L2 reading. Previous studies have also shown the key role of L2 proficiency and knowledge for the attenuation of cross-linguistic effects elicited by L1-L2 homographs or cognates (see for instance Libben & Titone, 2009; van Hell & Tanner, 2012). Such a relation has been previously observed at the neural level, with results highly in line with our present findings. For instance, Novitskiy et al. (2019) observed that the semantic N400 facilitation obtained during a cross-alphabetic Russian–English priming task was largely underpinned by the L2 vocabulary proficiency of their Russian–English participants. In another recent study (Fu et al., 2023), the ability to rapidly build up mental representations for L2 in bilinguals of distant L1-L2 (i.e., Chinese–English) was also found to be predicted by L2 proficiency and reflected in different modulations of N1 and P200 components across few repeated exposures to the novel words. Importantly, our study revealed for the first time differential modulation exerted by L2 proficiency across various stages and processes involved in both L1 and L2 reading. Specifically, L2 proficiency predicted lexical access as reflected in ERPs as early as at 30 ms regardless of the language of presentation. Furthermore, it modulated script processing at around 200 ms. Finally, it influenced the differential impact that script inconsistencies have on familiar and novel words at later lexico-semantic stages indexed by the N400 response. Beyond L2 proficiency, other study, however, shows a stronger contribution of inhibitory control mechanisms over L2 proficiency (Durlik et al., 2016; Pivneva et al., 2014) suggesting that an inhibition of the competing L1-L2 candidates is likely proportional to the amount of the activation and, therefore, to the L2 proficiency level, according to the Inhibitory Control Model (Abutalebi & Green, 2007; Green, 1998). Future studies will need to consider distinct and potentially interactive contributions from both cognitive control and L2 proficiency to the effective resolution of cross-script competition mechanisms during biliterate reading.

Conclusion

To conclude, the present study offers electrophysiological evidence detailing the time-course of the processing of cross-alphabetic inconsistencies during biliterate reading and elucidates the neural mechanisms underlying their resolution, likely driven by whole-form access of familiar words in both languages. The latter is evident in a functional dissociation between words and pseudowords, starting at early latencies. The cross-script ambiguity in L2 verbal stimuli without pre-existing mental representations seems to be detected only at late post-lexical stage, as indexed by increased N400 responses; however, for familiar words, this detection was already observed around 200 ms during an orthography-related stage, with higher P200 responses, likely indicating an attenuation of the L1-L2 inconsistencies by means of an enhanced whole-form lexical recognition strategy. Critically, this mid-latency effect may be triggered by the rapid and automatic activation of the lexico-semantic traces for these stimuli, commencing at the initial processing stages (~50 ms). Therefore, the interference experienced during L2 reading may be resolved by means of a top-down mechanism that provides a high-order lexico-semantic feedback during orthographic processing. Future ERP studies might consider testing a possible attenuation of cross-script incongruencies by adding semantic content to novel ambiguous L2 word-forms. This can be done, for example, by a short training under meaningful conditions, as successfully implemented in earlier-word learning studies using picture association (Perfetti et al., 2005; Shtyrov et al., 2022) or semantically constrained sentence processing (Batterink & Neville, 2011; Borovsky et al., 2012) tasks. This would provide strong evidence for the existence and, importantly, rapid building-up of interactive top-down mechanisms that ensure effective written communication in the L2. Another interesting question to address in future studies might be the naming performance for ambiguous stimuli along a particular task

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(namely, L1-L2 selection) and its cognitive and neural underpinnings.

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Appendix

1. Stimuli used in the study. Note that the same handwritten font was used across all tasks

L1 Script		L2 Script		Ambiguous Script	
Words	Pseudo-words	Words	Pseudo- Words	Words	Pseudo- Words
шаг	шаз	kid	kof	gap	gex
шок	шой	law	leq	pot	pex
лак	лец	vet	vaz	cop	рик
зал	зеж	jam	jod	nap	пем

2. List of stimuli extracted from Snodgrass and Vanderwart database used in the L2 picture naming task

High Familiarity		Medium Familiarity		Low Familiarity	
Item	Number in database	Item	Number in database	Item	Number in database
Eye	86	Corn	66	Drum	80
Key	128	Hammer	114	Balloon	15
Television	228	Potato	180	Wagon	249
Fork	3	Broom	37	Frog	100
Tree	241	Church	57	Kite	129
Shoe	204	Glove	106	Cow	68

(*Continued*)

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(*Continued.*)

High Familiarity		Medium Familiarity		Low Familiarity	
Item	Number in database	Item	Number in database	Item	Number in database
Bus	39	Ladder	131	Turtle	244
Knife	130	Fish	89	Elephant	84
Window	257	Nail	151	Axe	12
Clock	60	Lemon	135	Bell	25
Table	226	Ball	14	Pig	172
Lamp	132	Strawberry	220	Basket	20
Blouse	29	Screw	198	Lion	140
Envelope	85	Pumpkin	181	Bear	21
Cake	42	Rabbit	182	Kangaroo	126
Umbrella	245	Doll	74	Snake	209
Iron	123	Butterfly	40	Snail	208
Guitar	111	Peach	163	Caterpillar	50
Horse	121	Vase	246	Alligator	3
Arrow	8	Mountain	148	Anchor	4

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